

Improved Kelvin contacts boost current-sensing accuracy by an order of magnitude

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MANY POWER-SUPPLY designs rely on accurately sensing the voltage across a current-sense element. Multiphase regulators use the sense voltage to force current sharing among phases, and single-phase regulators to control the current-limit setpoint. As internal complexity and clock speeds increase, processors impose narrower operating margins for power-supply voltages and currents, which in turn make accurate current sensing critically important. The most accurate of several available methods involves inserting a low-value current-sensing resistor in the power supply's output path. Another popular technique uses the parasitic resistance of a switching regulator's output inductor as the sense element. For either method, currents of 20A or more per power-supply phase impose a sense-resistance limit of approximately 1 m Ω . Precision resistors of 1% accuracy are available at reasonable cost, but an error of 1% of 1 m Ω amounts to only 10 $\mu\Omega$.

The resistance of solder joints that attach a sense resistor or inductor can easily exceed 10 $\mu\Omega$ and, worse yet, can vary significantly during a production run. In the past, discrete four-wire resistors provided separate high-current and sense-voltage connections, allowing accurate Kelvin sensing and excluding voltage drops that the high-current connections introduce. Unfortunately, four-wire sense resistors or inductors are unavailable in low cost SMD packages. Thus, most power-supply designers use two-wire sense components and apply a Kelvin-connection pc-board-layout technique (Figure 1). However, test results reveal that applying conventional Kelvin sensing techniques to low-value resistors introduces transduction errors as high as 25%—an unacceptable error margin for designs that require high accuracy.

So, what's a power-supply designer to do? The answer involves a slight variation on an old idea that requires only a minor

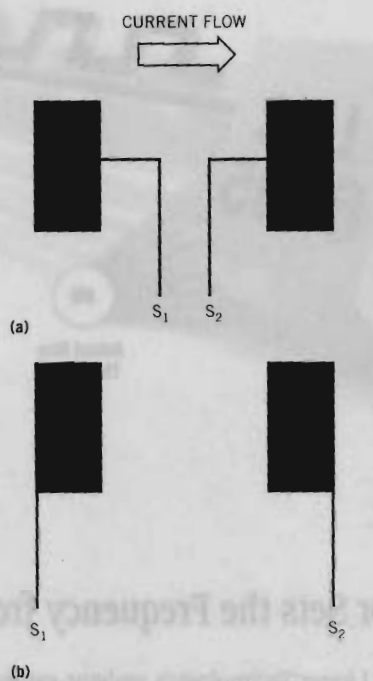


Figure 1 Conventional solder pads offer two choices for Kelvin connections: on the pads' inner edges (a) or outer corners (b).

change in a sense resistor's mounting footprint. To compare performance of conventional Kelvin connections versus the proposed method, a test board includes three pc-layout footprints for installation of 1-m Ω , 1%-accurate, surface-mount resistors. In all three patterns, current enters and exits the resistor via traces (not shown) on the pads' left and right sides, respectively.

In Figure 1a, applying a current of 4.004A produces a sense voltage at the Kelvin terminals of 4.058 mV, a 1.35% error. At 8.002A, the sense voltage at the Kelvin terminals measures 8.090 mV, a 1.1% error. In Figure 1b, a current of 4.004A produces a sense voltage at the Kelvin terminals of 5.01 mV, a 25% error. At 8.002A, the sense voltage at the Kelvin terminals measures 9.462 mV for an er-

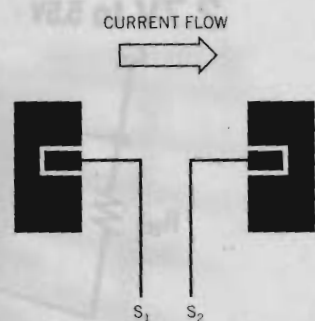


Figure 2 Modified pads provide isolated Kelvin connections that eliminate errors introduced by voltage drops across soldered connections carrying high current.

ror of 18.2%. Figure 2 shows an improved component footprint. Each large solder pad includes a central cutout area that partially surrounds a narrow pad that solders directly to the sense element and thus carries no current. This approach removes from the sense path the large-area solder joints that mount the part and carry high load current.

When you apply a current of 4.002A to the pads in Figure 2, voltage at the Kelvin terminals measures 4.004 mV, a 0.05% error. At 8.003A, the sense voltage measures 8.012 mV, an error of only 0.11% and an order of magnitude improvement over Figure 1a. Sense-voltage variation over temperature should greatly improve, and solder-thickness variation no longer affects the sense voltage. Best of all, the technique costs nothing to implement.

Obviously, the technique in Figure 2 works only with terminations sufficiently wide to allow dividing the solder pad into three sections and still retain adequate soldering area to handle the high-current connections. However, for many designs, this simple technique can significantly improve the accuracy of current sharing, V-I load-line characterization, and current-limit setpoints. □